

CONNECTIVE TISSUE DERIVED POLYPEPTIDES

TECHNICAL FIELD

The present invention relates to methods for treating and preventing arthritis and other degenerative diseases and to inducing tolerance in an individual to an antigenic component of cartilage, the present invention also relates to novel methods for preparing and recovering connective tissue derived polypeptides, their uses in methods of treatment, and protection of connective tissues in arthritis and other degenerative diseases.

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BACKGROUND OF THE INVENTION

I. General

As used in the specification and claims, the singular form "a," "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a fungal pathogen" includes a plurality of fungal pathogens, including mixtures thereof.

As used herein the term "derived from" shall be taken to indicate that a specified integer are obtained from a particular source albeit not necessarily directly from that source.

20 A "composition" is intended to mean a combination of active agent and another compound or composition, inert (for example, a detectable agent or label) or active, such as an adjuvant.

Unless the context requires otherwise or specifically stated to the contrary, integers, steps, or elements of the invention recited herein as singular integers, steps or 25 elements clearly encompass both singular and plural forms of the recited integers, steps or elements.

The embodiments of the invention described herein with respect to any single embodiment shall be taken to apply mutatis mutandis to any other embodiment of the invention described herein.

30 Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated step or element or integer or group of steps or elements or integers but not the exclusion of any other step or element or integer or group of elements or integers.

35 Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is

to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations or any two or more of said steps or features.

5 The present invention is not to be limited in scope by the specific examples described herein. Functionally equivalent products, compositions and methods are clearly within the scope of the invention, as described herein.

The present invention is performed without undue experimentation using, unless otherwise indicated, conventional techniques of molecular biology, microbiology, 10 virology, recombining DNA technology, peptide synthesis in solution, solid phase peptide synthesis, and immunology. Such procedures are described, for example, in the following texts that are incorporated herein by reference:

1. Sambrook, Fritsch & Maniatis, Molecular Cloning: A Laboratory Manual, Cold 15 Spring Harbor Laboratories, New York, Second Edition (1989), whole of Vols I, II, and III;
2. DNA Cloning: A Practical Approach, Vols. I and II (D. N. Glover, ed., 1985), IRL Press, Oxford, whole of text;
3. Oligonucleotide Synthesis: A Practical Approach (M. J. Gait, ed., 1984) IRL 20 Press, Oxford, whole of text, and particularly the papers therein by Gait, pp 1-22; Atkinson et al., pp35-81; Sproat et al., pp 83-115; and Wu et al., pp 135151;
4. Nucleic Acid Hybridization: A Practical Approach (B. D. Hames & S. J. Higgins, eds., 1985) IRL Press, Oxford, whole of text;
5. Perbal, B., A Practical Guide to Molecular Cloning (1984);
- 25 6. Wiinsch, E., ed. (1974) Synthese von Peptiden in Houben-Weyls Metoden der Organischen Chemie (Miiler, E., ed.), vol. 15, 4th edn., Parts 1 and 2, 30 Thieme, Stuttgart.
7. Handbook of Experimental Immunology, Vols. I-IV (D. M. Weir and C. C. Blackwell, eds., 1986, Blackwell Scientific Publications)

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Bibliographic details of the publications referred to in this specification are collected at the end of the description

2. Background art

35 Diseases of the musculoskeletal system such as rheumatoid arthritis (RA), osteoarthritis (OA), disc degeneration (DD), and osteoporosis (OP) are a major cause of

morbidity throughout the world. These diseases have a substantial influence on health and quality of life and inflict an enormous cost on health systems.

The aetiology of OA is considered to be multi-factorial with ageing, mechanical, hormonal and genetic factors all contributing to varying degrees. OA emerges as a 5 clinical syndrome when these etiological determinants result in sufficient joint tissue damage to cause synovial inflammation and the appearance of the symptoms of pain and impairment of function.

RA is thought to arise as a consequence of extrinsic and/or intrinsic triggering of an autoimmune response in genetically susceptible individuals. The aggressive 10 inflammation initiated in the joints of RA patients by the activation of their immune system is manifest by the release of pro-inflammatory cytokines, proteinases and free radicals. All of these mediators have the ability to promote the destruction of cartilage, bone and other intra-articular joint tissues leading to further impairment of joint function and progression of the disease. While both OA and RA show common 15 pathological features of cartilage destruction and synovial inflammation, the origins and temporal history of these events are clearly distinct. Nevertheless, destruction of joint cartilage is common to both OA and RA and there is now strong evidence that the breakdown and release of the matrix components from cartilage play a significant role in the chronicity of these diseases.

20 Cartilage may be considered as an anisotropic biomaterial composed essentially of a three-dimensional fibrous network of type II collagen fibrils copolymerised with types IX and XI collagens embedded in a proteoglycan (PG) rich hydrated extracellular matrix. Type II collagen accounts for over 90% of the total collagen of adult cartilage while the type IX content is only 1-2%.

25 Type IX collagen is a heteropolymer consisting of three genetically distinct alpha chains, $\alpha 1(IX)$, $\alpha 2(IX)$ and $\alpha 3(IX)$ whose molecular structure and amino acid sequences have been described (Pihlajamaa T, et al. Characterisation of recombinant human type IX collagen, association of α chains into homotrimeric and heterotrimeric molecules. J Biol Chem, 274: 22464-22468, 1999)(US Patent 6,127,523, October 3, 30 2000). The type IX α -chains contain 3 triple-helical domains, COL1, COL2 and COL3 and four non-collagenous domains, NC1, NC2, NC3 and NC4. The NC1 and NC3 regions contain cysteine residues that can form intramolecular disulfide linkages between the α -chains. Only the $\alpha 1(IX)$ chain contains a NC4 domain (see Figure 1) and the sequence from chick sternia has been shown to consist of 243 amino acid 35 residues with a calculated molecular mass of 27,139Da and overall positive charge (Vasios G, Nishimura I, Konomi H, van der Rest M, Cartilage Type IX collagen-

proteoglycan contains a large amino-terminal globular domain encoded by multiple exons. *J Biol Chem* 263: 2324-2329, 1988).

The type IX collagen heteropolymer is linear except that the NC3 domain acts like a hinge allowing the NC4 region of the $\alpha 1$ chain to project away from the other 5 chains. Interestingly, a single chondroitin sulfate chain is attached to the NC3 domain.

Although only a minor component of cartilage, type IX collagen provides an important role in maintaining the type II collagen fibrous network assembly which is essential for the optimum physical function of this weight-bearing tissue. Type IX collagen resides on the surface of the type II collagen fibrils to which it is covalently 10 linked via, at least 2 trivalent pyridinoline cross-links, particularly at sites where the type II fibril network intersects. By cross-linking the type II collagen fibrils type IX collagen would appear to constrain the expansion caused by the imbibition of water molecules attracted into the tissue by the trapped negatively charged proteoglycan (PG) aggregates (referred to herein as aggrecans). In addition the positively charge centres 15 on the globular NC4 domain also provides a potential binding site for the polyanionic aggrecans.

The aggrecans of cartilage are macro-molecular aggregates of PG subunits which are non-covalently attached along the length of a hyaluronic acid chain. Each aggrecan may contain 20-50 PG subunits and their interaction with the HA backbone is 20 stabilised by ternary interactions with link protein. The PG subunits consist of a protein core to which up to 100 GAG chains are covalently linked. The major GAG constituents of the PGs are the chondroitin sulfates (ChS) and keratan sulfate.

In addition to the collagens and proteoglycans, cartilage also contains a large 25 number of non-collagenous proteins, the most abundant being cartilage oligomeric protein (COMP), cartilage matrix protein (CMP), and thrombospondin. COMP is considered to be a key structural component of the cartilage matrix since it interacts with type IX collagen and plays a role in the development and assembly of type II collagen fibrils (Holden P, et al. Cartilage oligomericmatrix protein interacts with type IX collagen and disruptions to these interactions identify a pathogenic mechanism in a 30 bone displasia familly. *J Biol Chem*, 276: 6046-6055, 2001). In the early stages of arthritis when cartilage breakdown is increased, PGs, type IX collagen and COMP fragments are some of the first matrix components to be released into synovial fluid by the action of endogenous proteinases. These products of cartilage breakdown have been shown to be antigenic and can induce an inflammatory response within arthritic 35 joints thereby contributing to the rate of disease progression.

- In arthritic diseases, the excessive breakdown of cartilage and bone and the concomitant elicitation of an inflammatory reaction provoked by the release of autoantigens are responsible for their chronicity. However, there is accumulating evidence to indicate that these matrix molecules could also be responsible for the initiation of joint diseases by acting as autoantigens. Indeed, systemic administration of type II collagen or other matrix components together with adjuvants to laboratory animals have been used to produce animal models of arthritic disease (Creamer MA, Rosloniec EF, Kang AH. The cartilage collagens: a review of their structure, organization and role in the pathogenesis of experimental arthritis in animals and human rheumatic disease, *J Mol Med*, **76**: 275-288, 1998).

In the case of cartilage collagens, this knowledge has led to the development of means of treating rheumatic diseases by using the concept of oral tolerisation (Weiner, HL, Komagata Y. Oral tolerance and the treatment of Rheumatoid Arthritis. *Seminars Immunopath*, **20**: 289-308, 1998). Thus it has been shown that suppression of type II collagen-induced arthritis in animal models can be achieved by oral administration of low doses of type II collagen. Oral tolerisation of arthritic patients by administration of type II collagen has also been shown to be effective clinically and therapeutic effects have been reported with small (less than 100mg) daily doses of type II collagen antigens. Studies using rheumatoid and juvenile rheumatoid arthritis patients confirmed the efficacy and safety of low daily oral doses of type II collagen derived from chick sterna (Trentham D, et al. Effects of oral administration of type II collagen on rheumatoid arthritis. *Science*, **261**: 1727-1730, 1993) (Barnett *et al*, A pilot study of oral type II collagen in the treatment of juvenile rheumatoid arthritis. *Arthritis. Rheum.* **39**:623-628, 1996). Other studies have indicated that cartilage collagens obtained from bovine sources were less effective than those prepared from chick cartilage.

Unfortunately, some studies have found that high doses of type II collagen may in fact exacerbate disease since, as already indicated, this cartilage derived antigen is also an arthritogen and it is difficult to accurately determine how much of this antigen would be effective or detrimental to the arthritic process. With regard to other cartilage collagens types X, XI are arthritogenic, while type IX collagen has been reported to be not as effective as type II collagen as a tolerant in some animal arthritis models (Lu S *et al*, Different therapeutic and bystander effects by intranasal administration of homologous type II and type IX collagens on the collagen- induced arthritis and Pristane-induced arthritis in rats. *Clin Immunol*. **90**:119-127, 1999).

35 In another study using recombinantly produced in-tact native type IX collagen it was found that when it was given orally to B10 congenic mice this collagen was able to

ameliorate the arthritis produced by prior inoculation with type II collagen (collagen induced arthritis, CIA). The recombinant type IX collagen was also tested for immunogenicity in other murine models and unlike type II collagen, it failed to induce overt arthritis in mice immunized with this protein (Myers L K *et al*, Immunogenicity 5 of recombinant Type IX collagen in murine collagen-induced arthritis. *Arthritis Rheum.* 46:1086-1093, 2002).

The discrepancy between the Lu et al (1999) and Myers et al (2002) may be explained by differences in the purity and molecular size of the type IX collagen preparations. Recombinant technology is considered the only means of obtaining pure 10 native type IX collagen since very little can be extracted from the cartilage matrix without using proteolysis as it is covalently bound to the type II collagen fibrils. The most common proteinase used to extract type IX collagen from cartilages is pepsin which is a commercial preparation generally derived from porcine stomach mucosa. Pepsin is not present in cartilage. This enzyme hydrolyses the non-collagenous 15 domains of the type IX molecule releasing the native COL1, COL2, and COL3 triple helical segments which are isolated from the mixture by precipitation leaving the partially degraded non-helical NC domains in solution.

The endogenous proteinases responsible for the normal turnover of type IX collagen in cartilaginous tissues are presently unknown. However, the matrix 20 metalloproteinase (MMP) family, the serine proteinases and cysteine proteinases are all known to degrade type IX collagen *in vitro* in both the helical (COL) and non-helical (NC) domains.

SUMMARY OF INVENTION

25 In work leading up to the present invention, the inventor sought to recover connective tissue derived polypeptides having anti-arthritis or anti-inflammatory activity. The inventor found that polypeptides produced by autolysis of connective tissue and having a molecular weight of less than 30,000Da had anti-arthritis or anti-inflammatoary activity.

30 The inventor also found that administration of a composition comprising one or more connective tissue derived polypeptides having a molecular weight of less than 30,000Da, tolerised individuals to antigenic components of cartilage and prevented the appearance of symptoms of arthritis.

Analysis of the polypeptides using proteomic techniques showed that fragments of the polypeptide produced by their tryptic digestion had strong identity with the NC4 domain of collagen type IX alpha 1 chain.

- Accordingly, the present invention relates to the use of a polypeptide comprising
- 5 a collagen type IX alpha 1 chain NC4 domain or biologically active fragment thereof having anti-arthritis or anti-inflammatory activity for the treatment or prevention of arthritis or other degenerative disease of the musculoskeletal system in an individual.

- In a first aspect the invention provides a pharmaceutical composition for treating or preventing arthritis or other degenerative disease in an individual, said composition
- 10 comprising a polypeptide comprising a collagen type IX alpha 1 chain NC4 domain or biologically active fragment thereof having anti-arthritis or anti-inflammatory activity in combination with a pharmaceutically acceptable carrier. In a preferred embodiment, the polypeptide has a molecular weight of less than 30,000Da and/or an amino acid length of less than 250 amino acids. In a further preferred embodiment, the
- 15 polypeptide or biologically active fragment thereof is derived from a mammal.

- In another aspect the invention provides a pharmaceutical composition for inducing tolerance in an individual to at least one antigenic component of cartilage, said composition comprising a polypeptide comprising collagen type IX alpha 1 chain NC4 domain or biologically active fragment thereof having anti-arthritis or anti-
- 20 inflammatory activity in combination with a pharmaceutically acceptable carrier. In a preferred embodiment the collagen type IX alpha 1 chain NC4 domain polypeptide has a molecular weight of less than 30,000Da or an amino acid length of less than 250 amino acids.

- In one example, the collagen type IX alpha 1 chain NC4 domain comprises
- 25 (i) an amino acid sequence as provided in SEQ ID NO 1, SEQ ID NO 14, SEQ ID NO 16, or SEQ ID NO 18,
- (ii) an amino acid sequence which is at least 70% identical to either SEQ ID NO 1, SEQ ID NO 14, SEQ ID NO 16, or SEQ ID NO 18, or
- (iii) a biologically active fragment of (i) or (ii).

- 30 Preferably, the collagen type IX alpha 1 chain NC4 domain comprises an amino acid sequence which is at least 75%, preferably 80%, 85%, 90% or 95% identical to any one of SEQ ID NO 1, SEQ ID NO 14, SEQ ID NO 16, or SEQ ID NO 18.

- In one example, the collagen type IX alpha 1 chain NC4 domain comprises:
- 35 (i) an amino acid sequence as provided in residues 21-182 of SEQ ID NO 1; residues 60-181 of SEQ ID NO 1; residues 72-181 of SEQ ID NO 1, residues 98-182 of SEQ ID NO 1, or residues 123-182 of SEQ ID NO 1; or

(ii) an amino acid sequence as provided in residues 24 - 268 of SEQ ID NO 14; residues 29 - 268 of SEQ ID NO 14, residues 29 - 215 of SEQ ID NO 14, residues 29-209 of SEQ ID NO 14, residues 29 - 208 of SEQ ID NO 14, residues 29 - 96 of SEQ ID NO 14, or residues 108 - 208 of SEQ ID NO 14.

5 In another example, the collagen type IX alpha 1 chain NC4 domain comprises at least one of SEQ ID NOS 2-11.

In a preferred embodiment, inducing tolerance in the individual prevents at least one symptom of arthritis or other musculoskeletal degenerative condition in the individual.

10 As used herein to "prevent at least one symptom" refers to defending against or inhibiting a symptom, delaying the appearance of a symptom, reducing the severity of the development of a symptom, and/or reducing the number or type of symptoms suffered by an individual, as compared to not administering a pharmaceutical composition comprising a polypeptide of the invention. Accordingly, throughout this
15 description, it will be understood that any clinically or statistically significant attenuation of even one symptom of a musculoskeletal degenerative condition pursuant to the treatment according to the present invention is within the scope of the invention.

The present invention also provides a method of inducing tolerance in an individual to at least one antigenic component of cartilage comprising administering the
20 individual with an effective amount of the pharmaceutical composition according to the first aspect of the invention.

Preferably the method of inducing tolerance in the individual prevents the onset of the musculoskeletal degenerative condition.

Accordingly, the invention provides a method for preventing a musculoskeletal
25 degenerative condition in an individual comprising administering a pharmaceutically effective amount of a composition according to the first aspect to the individual.

Further, the invention provides a method for preventing an autoimmune response to at least one antigenic component of cartilage comprising administering a composition according to the first aspect of the individual.

30 In related aspects, the invention further provides for use of a polypeptide comprising a collagen type IX alpha 1 chain NC4 domain or biologically active fragment having anti-arthritis or anti-inflammatory activity in combination with a pharmaceutically acceptable carrier in the manufacture of a medicament for inducing tolerance to at least one antigenic component of cartilage or for preventing a
35 musculoskeletal degenerative condition in an individual.

Preferably, the pharmaceutical composition of the present invention is one which prevents at least one symptom of arthritis, such as for example inflammation, joint tenderness, joint swelling, joint stiffness, restricted mobility, or strength reduction, when administered to a naive individual.

5 In one example, the individual is a naive individual. By "naïve individual" is meant that preferably the individual does not present two or more symptoms of a musculoskeletal degenerative condition, more preferably the individual does not present a symptom of a musculoskeletal degenerative condition. This may be prior to or during or post the course of a musculoskeletal disease.

10 In a further aspect, the present invention provides methods for recovering polypeptides having a molecular weight of less than 30,000Da from connective tissue wherein connective tissue particles are subjected to autolysis in the presence of an autolysis medium such that a mixture of glycosaminoglycan peptides and polypeptides are released from the connective tissue particles into the autolysis medium. The 15 process of inducing autolysis has previously been described in PCT/AU03/00061 (in the name of the Applicant), which is incorporated herein by reference. According to the invention, polypeptides are recovered from the medium and are separated according to size. The invention also provides methods for separating and identifying the recovered polypeptides according to their size and charge.

20 Accordingly, in one example the method for preparing a polypeptide having anti-arthritis or anti-inflammatory activity comprises isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide.

25 In a related example, the present invention provides a method for preparing a polypeptide having anti-arthritis or anti-inflammatory activity, the method comprising
(i) incubating a connective tissue in an autolysis medium that provides a buffered pH range of between about pH 2.5 and about pH 8.5 for a time and under conditions sufficient to release a GAG-peptide and a polypeptide having a molecular weight of 30 less than 30,000Da,
(ii) recovering a mixture comprising the GAG-peptide and polypeptide from the autolysis medium;
(iii) separating the polypeptide from the GAG-peptide; and
(iv) recovering the polypeptide having a molecular weight of less than 30,000Da.

35 Any well known techniques such as for example, chromatography, ion exchange techniques, gel filtration (eg. diafiltration or ultrafiltration), gel electrophoresis (eg. one

dimensional or two dimensional) or any other method of separating and/or recovering polypeptides according to their size and molecular weight, or combination thereof, can be used to recover the polypeptide from the mixture.

A combination of the same or similar techniques may be used and may be repeated. In this way, fractions of polypeptides of different molecular weight ranges may be obtained and individual polypeptides can also be recovered.

Polypeptides recovered by the method of the invention are connective tissue derived polypeptides. The present invention clearly contemplates that the recovered polypeptides may comprise mixtures of polypeptides or individual polypeptides.

10 The inventor has found that the recovered polypeptides and mixtures thereof have enhanced and/or different pharmacological activities to the GAG-peptide/polypeptide mixture. The polypeptides according to the present invention are those connective-tissue derived polypeptides having anti-arthritis or anti-inflammatory activity. In one embodiment, a polypeptide of the invention reduces rear paw inflammation in rats with collagen induced arthritis. In another embodiment, a polypeptide of the invention decreases tail inflammation in rats with collagen induced arthritis. In another embodiment, a polypeptide of the invention decreases fore paw inflammation in rats with collagen induced arthritis. In yet another embodiment, a polypeptide of the invention decreases weight loss in rats with collagen induced arthritis.

15 Accordingly, another example of the present invention provides a connective tissue derived polypeptide, having a molecular weight of less than 30,000Da which is obtainable by the method of the invention, and having anti-arthritis or anti-inflammatory activity.

20 25 For example, the invention provides a connective tissue derived polypeptide having a molecular weight of less than 30,000Da which is obtainable by:

(i) incubating a connective tissue in an autolysis medium that provides a buffered pH range of between about pH 2.5 and about pH 8.5 for a time and under conditions sufficient to release a GAG-peptide and a polypeptide having a molecular weight of

30 less than 30,000Da,

(ii) recovering a mixture comprising the GAG-peptide and polypeptide from the autolysis medium;

(iii) separating the polypeptide from the GAG-peptide; and

(iv) recovering the polypeptide having a molecular weight of less than 30,000Da.

35 In one example, the recovered polypeptide comprises a non-collagenous region-4 (NC4) of the collagen type IX α 1 chain, or biologically active fragment thereof.

- The effects observed for the polypeptides of the invention on rats with collagen induced arthritis also provide application for the polypeptides in the treatment, protection and restoration of connective tissues in inflammatory and degenerative tissue diseases such as rheumatoid arthritis and osteoarthritis in all animals. Preferably, the 5 polypeptides of the present invention prevent antigen driven autoimmune diseases in animals. In another preferred embodiment, polypeptides of the invention reduce symptoms associated with antigen driven autoimmune diseases in animals.

Accordingly, it is to be understood that the forgoing examples apply *mutatis mutandis* to each and every aspect of the invention.

- 10 Accordingly, the invention provides a pharmaceutical composition for treating or preventing arthritis or other musculoskeletal degenerative disease in an individual, said composition comprising one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide 15 having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide.

- 20 The invention also provides a pharmaceutical composition for inducing tolerance in an individual to at least one antigenic component of cartilage, said composition comprising one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide having a molecular weight of less than 30,000Da.

- 25 Preferably, inducing tolerance in the individual prevents at least one symptom of a musculoskeletal degenerative disease in the individual.

- In another example, the present invention provides a method for preventing a musculoskeletal degenerative condition in an individual comprising administering the 30 individual with an effective amount of a pharmaceutical composition comprising one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide having a molecular weight of less than 35 30,000Da.

- In another example, the present invention provides a method for preventing autoimmune response in an individual to at least one antigenic component of cartilage comprising administering the individual with an effective amount of a pharmaceutical composition comprising one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide having a molecular weight of less than 30,000Da.
- The present invention further provides a method of inducing cartilage formation in an individual, comprising administering to the individual an effective amount of a connective tissue derived polypeptide according to the invention and having anti-arthritis or anti-inflammatory activity, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide having a molecular weight of less than 30,000Da.
- In other related examples, the present invention provides for use of one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, in the preparation of a medicament for the treatment or prevention of arthritis or other musculoskeletal disease in a subject, wherein said polypeptide is obtainable by the method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide.
- In one example the invention provides for the use of one or more connective tissue derived polypeptides having anti-arthritis or anti-inflammatory, in the preparation of a medicament for tolerising an individual to at least one antigenic component of cartilage, wherein said polypeptide is obtainable by a method comprising isolating a mixture comprising a GAG-peptide and a polypeptide having a molecular weight of less than 30,000Da by autolysis from connective tissue, separating the GAG-peptide from the polypeptide, and recovering the polypeptide having a molecular weight of less than 30,000Da.
- It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly

described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

DETAILED DESCRIPTION OF THE FIGURES

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Figure 1 is a schematic representation of the Human type IX collagen molecule showing the 3 α chains which constitute the heteropolymer and their collagenous (COL) and non-collagenous (NC) domains. The COL regions are triple helical while the NC domains are non-helical. Cysteine residues in the NC3 and NC1 Regions allow

10 disulfide bond interactions. NC4 is only present on the α_1 (IX) chain and is overall positively charged allowing it to interact with polyanionic glycosaminoglycans in the extracellular matrix. A single chondroitin sulfate chain is attached, via a serine residue, to the NC3 region of the α_2 (IX) chain in the native molecule.

15 Figure 2 is a schematic diagram of the methods used for the separation and sub-fractionation of the glycosaminoglycan peptide and polypeptide mixture (eg calcium peptacan (CaP)) into purified GAG-peptides and polypeptides using ion exchange media.

20 Figure 3 is a photographic representation of the SDS-PAGE 1-D electrophoresis of the proteins/polypeptides isolated from the glycosaminoglycan-peptide and polypeptide mixture (CaP) using the ion-exchange schema shown in Figure 2.

25 Figure 4 is a photographic representation of the SDS-PAGE 2-D electrophoresis of the proteins/polypeptides isolated from the glycosaminoglycan-peptide and polypeptide mixture (CaP) using the ion-exchange schema shown in Figure 2. The majority of the spots resolved by this procedure were isolated and subjected to trypsin digestion sequence analysis using Matrix Assisted Laser Desorption Ionisation mass spectrometry (MALDI-MS).

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Figure 5 identifies the polypeptides separated by the SDS-PAGE 2-D electrophoresis after tryptic digestion and MALDI-MS of the cleaved fragments determined by comparison with corresponding trypsin digestion fragments available in published databases.

Figure 6 is a table of the physical characteristics (MW and pI) of protein fragments polypeptides found in Calcium Peptacan after ion-exchange treatment and 2D electrophoresis as described in Figure 4.

- 5 Figure 7 is (i) an amino acid sequence of cartilage oligomeric matrix protein (fragment) - bovine and (ii) an amino acid sequence for odorant binding protein - bovine obtained from the ExPASy TrEMBL database on which the peptide sequences obtained from the peptide mass fingerprinting of gel spots 2 and 19 respectively have been superimposed as bolded type where they are identical.

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- Figure 8 is a map of the partial sequence of the bovine NC4 domain of type IX collagen alpha 1 chain sequence obtained from the ExPASy TrEMBL database on which the peptide sequences obtained from the peptide mass fingerprinting of gel spot 13 (Figure 4) has been superimposed as bolded type where they are identical. The sequence match for spot 13 is 62% but all the spots identified from Figure 4 found to be related to the collagen $\alpha 1(IX)$ -chain contained the 173-181 peptide present on the bovine $\alpha 1(IX)$ -NC4 domain. The nearest peptide to the N-terminus is the 21-39 peptide. All the spots identified as from type IX collagen except 10 and 15 had this peptide. The nearest peptide sequence match to the C-terminus at 187 was the peptide 173-181 which was present in all the $\alpha 1(IX)$ -NC4 spots identified by MALDI-MS.

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- Figure 9 is the amino acid sequence of the NC4 domain of the type IX collagen alpha 1 chain from 17 day old chick embryos sterna as reported by Vasio et al. (J Biological Chem. 263, 2324-2329, 1998) on which the amino acid sequences identified from the 20 MALDI-MS analysis of the polypeptides separated by 2D electrophoresis have been superimposed indicating where the sequences are identical as bold type and underlined.

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- Figure 10 shows the human NC4 domain of the type IX collagen alpha 1 chain (sequences 24-268) obtained from the Swiss-Prot & TrEMBL data-bases (released 07-June-2004) on which the amino acid sequences identified from the MALDI-MS analysis of the polypeptides separated by 2D electrophoresis have been superimposed showing where the sequences are identical as bold type and underlined. Sequence 1-23 is the signal sequence for the human NC4 domain of the type IX collagen alpha 1 chain.

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Figure 11 is summary of the tolerogenic and prophylactic/therapeutic protocols used to evaluate the antiarthritic effects of the polypeptides INR-195 and INR-126 in the rat collagen induced arthritis (CIA) model.

- 5 Figure 12 shows the results obtained for the anti-arthritic effects of the polypeptide fractions INR-126, INR-195 and the established anti-rheumatoid arthritis drug, aurothiomalate (ATM) using the rat CIA-prophylactic/therapeutic protocol. Note that INR-126 and INR-195 appear to show similar anti-arthritic activities at 20 mg/kg and are both superior to ATM in this animal model.

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Figure 13 shows the results obtained for the anti-arthritic effects of the polypeptide fractions INR-126, INR-195 using the rat CIA-tolerogenic protocol. Note that the smaller MW fraction INR-126 appears to exhibit a more longer lasting tolerogenic activity than the higher MW fraction, INR-195.

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Figure 14 show representative photomicrographs of stained histological sections, prepared and stained using standard methods, of hind-paw joints from normal and the untreated rat collagen induced arthritis (CIA) model at day 18 showing the extent of inflammatory cell invasion and destruction of tendons, cartilage and bone.

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Figure 15 shows representative photomicrographs of stained histological sections, prepared and stained using standard methods, of hind-paw joints from normal and the rat collagen induced arthritis (CIA) model at day 18 of animals treated orally with the polypeptides INR-126 (20mg/kg) and INR195 (20mg/kg) using the tolerogenic or

- 25 prophylactic/therapeutic protocols. Note the reduction of the inflammatory cell invasion and destruction of tendons, cartilage and bone compared to the untreated groups shown in Figure 14.

30 DETAILED DESCRIPTION OF THE INVENTION

1. Autolysis

Connective tissue is an animal tissue that supports organs, fills the spaces between them, and forms tendons and ligaments. The term "tissue" as used herein

refers to a group of similarly specialised cells that perform a common function. As used herein, tissue is intended to include an organ composed of a given tissue and to the cells, individually or collectively, that compose the tissue.

- In one embodiment, the connective tissue is a cartilage. In another embodiment, 5 the connective tissue is non-cartilage material eg. lung, skin, bone, ligament or tendon.

Preferably the cartilage is tracheal, articular, auricular, nasal, sternal, rib skeletal, or antler cartilage. Cartilage may, however, be any type of cartilage.

Connective tissue may be obtained from any animal having connective tissue.

- In one embodiment, connective tissue is selected from any one of the following: 10 human, bovine, ovine, porcine, equine, avian, cervine and piscine species. Preferably the connective tissue is bovine, ovine, porcine, cervine, shark or equine.

In one embodiment tissues from young animals are preferable eg a calf. In an alternate embodiment a more mature animal is preferred.

- The connective tissue may be treated and washed as required by methods known 15 in the art to remove any adhering soft tissues. In one embodiment the connective tissue is reduced to a particle size. In an alternate embodiment the connective tissue is not reduced to a particle size.

- The connective tissue can be reduced to a particle size by means including, but not limited to, mincing, dicing, grinding and the like. In one embodiment particle 20 diameter is less than about 5mm, preferably less than about 4mm, more preferably less than about 3mm. Most preferably, the particle diameter is about 0.1mm to about 3mm.

- The terms "incubate" or "incubating" mean to maintain (a chemical or biochemical system) under specific conditions in order to promote a particular reaction.

- As used herein the term "autolysis" refers to the digestion of cellular 25 components by endogenous hydrolases and proteinases released from lysosomes or associated with the cell and its pericellular matrix following cell death, causing self digestion of tissue. A person skilled in the art will appreciate that the rate of autolysis will vary with many factors including pH, temperature, concentration, tissue type, tissue particle size and time of incubation.

- The term "buffer" refers to a compound, usually a salt, which, when dissolved in an aqueous medium serves to maintain the free hydrogen ion concentration of the solution within a certain pH range, when hydrogen ions are added or removed from the solution. A salt or solution is said to have a "buffering capacity" or to buffer the solution over such a range, when it provides this function. Generally a buffer will have 30 adequate buffering capacity over a range that is within \pm 1pH unit of its pK.

In one embodiment the salt is a monovalent salt. Preferably the monovalent salt is selected from any one or more of hydrogen, sodium, potassium, or ammonium. In an alternate embodiment the salt is not a monovalent salt. In another embodiment the salt is a divalent salt selected from any one or more of calcium, magnesium, copper, or zinc. Most preferably the salt is calcium or magnesium.

In one embodiment the pH is in the range of about 2.5 to about 8.5, preferably about 3.5 to about 8.0, more preferably about 4 to about 7 and most preferably about 4.5 to about 7.

The term "condition" refers to other factors which affect the rate, efficiency and amount of autolysis, such as, for example, temperature and time.

In one embodiment the temperature conditions for carrying out the step of autolysis is in the range of from about 20°C to about 45°C, preferably about 25°C to about 45°C, more preferably about 32°C to about 45°C, more preferably about 32°C to about 40°C most preferably about 37°C.

In one embodiment, the autolysis takes up to 48 hours, preferably up to 36 hours, preferably up to 24, preferably up to 16 hours, more preferably 16-24 hours.

In a preferred embodiment, cartilage particles of size 1-3mm are subject to autolysis in an aqueous medium at a pH of 4-5 and temperature of 32-45°C for 16-24 hours.

Glycosaminoglycan (GAG) refers to the polysaccharide chains of proteoglycans, which are composed of repeating disaccharide units containing a derivative of an amino sugar (either glucosamine or galactosamine) glycosidically linked to glucuronic or iduronic acid. The most common derivatives being O-sulfated esters substituted in the 4 or 6 positions of the N-acetylated glucosamine or galactosamine rings.

Examples of GAGs include hyaluronic acid (hyaluronan) (which is non-sulfated), chondroitin sulfate, keratan sulfate and heparan sulfate.

The terms "protein", "polypeptide", or "peptide", when used herein are interchangeable and refer to amino acids in a polymeric form of any length.

GAG-peptides and polypeptides can be recovered from the autolysis medium with well known methods. For example, in one embodiment, the residual tissue particles are removed by filtration from the autolysis media and the mixture of GAG-peptide complexes and polypeptides recovered from the supernatant. In another embodiment, the residual tissue particles are not removed from the autolysis medium.

In one embodiment, the supernatant is neutralised by addition of an alkaline solution containing a cation.

In one embodiment the supernatant is freeze dried. In an alternate embodiment the supernatant is not freeze dried.

- Alternatively the mixture of GAG-peptide and polypeptide is recovered from the autolysis medium or supernatant by precipitation with excess quantities of acetone, or aliphatic alcohols, such as, for example, ethanol or methanol. In another embodiment, the mixture of GAG-peptide and polypeptide is recovered from the autolysis medium or supernatant by the formation of water insoluble complexes with quaternary ammonium salts such as cetyl pyridinium, chloride. In another embodiment the mixture of GAG-peptide and polypeptide are recovered from the autolysis medium or supernatant by separation using size exclusion or ion-exchange or other forms of column chromatography or membrane filtration technology.

2. Separating and recovering the polypeptides of the invention

- Following recovery of the mixture of the GAG-peptide and polypeptide, the polypeptide and GAG-peptide can be separated by methods well known in the art.

- Preferably, the mixture of the GAG-peptide and the polypeptide is subjected to an ion exchange technique. In one embodiment the mixture of the GAG-peptide and the polypeptide is subjected to ion exchange solid phase media. In one embodiment the solid phase media is DEAE sepharose. In a preferred embodiment, the solid phase media is pre-swollen DEAE-Sepharose-6B.

- Recovery of the polypeptide refers to any well known separation technique. In one embodiment the polypeptide can be recovered by, for example, chromatography, ion exchange techniques, gel filtration (eg. diafiltration or ultrafiltration), gel electrophoresis (eg. one dimensional or two dimensional) or any other method of separating polypeptides according to their size and molecular weight, or combination thereof, and which is capable of recovering polypeptides having a molecular weight of less than 30,000Da.

- A combination of the same or similar separation techniques may be used and may be repeated. In this way, fractions of polypeptides of different molecular weight ranges may be obtained and individual polypeptides can also be recovered. It will be understood that separation of polypeptides according to size and molecular may be performed in any order.

- Accordingly, in one example the recovered polypeptides are subjected to a separation technique to recover polypeptides having a molecular weight of greater than 1,000Da. The recovered polypeptides having a molecular weight of greater than 1,000Da are subjected to a separation technique to recover polypeptides having a

molecular weight of less than 30,000Da. Accordingly, in one example the polypeptides have a molecular weight of less than 30,000Da and greater than 1,000Da.

In another example, the recovered polypeptides are subjected to a separation technique to recover polypeptides having a molecular weight of greater than 1,000Da
5 and then subjected to a separation technique to recover polypeptides having a molecular weight of greater than 10,000Da.

Accordingly, examples of the invention relate to the recover of polypeptides having a molecular weight of less than 30,000Da, less than 30,000Da and greater than about 1,000Da, and less than 30,000 and greater than 10,000.

10 In a further embodiment, the present invention comprises separating the one or more recovered polypeptides to recover individual polypeptides. Separation can be performed according to any well known techniques such as for example chromatography, one dimensional gel electrophoresis, two dimensional electrophoresis or the like.

15 The inventors have further analysed and identified the individual polypeptides separated by the method of the present invention.

Polypeptides recovered by the method of the invention are connective tissue derived polypeptides. The inventors have found that the recovered polypeptides and mixtures thereof have enhanced and/or different pharmacological activities to the
20 GAG-peptide/polypeptide mixtures.

Accordingly, the present invention provides a connective tissue derived polypeptide, obtainable by the method of the invention, having anti-arthritis or anti-inflammatory activity. In one embodiment, polypeptides of the invention and mixtures thereof reduce rear paw inflammation in rats with collagen induced arthritis. In another
25 embodiment, polypeptides of the invention and mixtures thereof decrease tail inflammation in rats with collagen induced arthritis. In another embodiment, polypeptides decrease fore paw inflammation in rats with collagen induced arthritis. In yet another embodiment, polypeptides of the invention and mixtures thereof decrease weight loss in rats with collagen induced arthritis.

30 As used herein the term "derived" shall be taken to indicate that a specified integer may be obtained from a source, albeit not necessarily directly from that source.

In an alternate embodiment, the polypeptides of the present invention are connective tissue derived polypeptides obtainable by the methods of the present invention having a molecular weight in the range of less than about 30,000Da and
35 having anti-arthritis or anti-inflammatory.

In an alternate embodiment, the polypeptides of the present invention are connective tissue derived polypeptides obtainable by the methods of the present invention having a molecular weight in the range of about 1,000Da and about 30,000Da and having anti-arthritis or anti-inflammatory.

5 In an alternate embodiment, the polypeptides of the present invention are connective tissue derived polypeptides obtainable by the methods of the present invention having a molecular weight in the range of about 10,000Da and about 30,000Da and having anti-arthritis or anti-inflammatory.

10 In another embodiment, the polypeptides of the present invention are connective tissue derived polypeptides obtainable by the methods of the present invention, having a molecular weight in the range of about 25,000Da and about 30,000Da and having anti-arthritis or anti-inflammatory.

Mixtures of polypeptides which have a molecular weight in a desired range are clearly contemplated.

15 In another embodiment, individual polypeptides obtainable by the methods of the invention having anti-arthritis or anti-inflammatory are contemplated. In one example the connective tissue derived polypeptides of the present invention have a molecular weight of about 27,000Da.

20 In a preferred example, the present invention provides a connective tissue derived polypeptide having a molecular weight of about 10,000Da to about 30,000Da, having anti-arthritis or anti-inflammatory and selected from the group consisting of:

- (a) a connective tissue derived polypeptide having an isoelectric point (pI) of about 6 to about 6.5, and more preferably a pI value of about 6.3 as determined by isoelectric focussing.
- 25 (b) a connective tissue derived polypeptide having an isoelectric point (pI) of about 6.5 to about 7, and more preferably a pI value of about 6.8 as determined by isoelectric focussing
- (c) a connective tissue derived polypeptide having an isoelectric point (pI) of about 7.5 to about 8.5, and more preferably a pI value of about 7.8 as determined by isoelectric focussing
- 30 (d) a connective tissue derived polypeptide having an isoelectric point (pI) of about 8 to about 8.5, and more preferably a pI value of about 8.2 as determined by isoelectric focussing
- (e) a connective tissue derived polypeptide having an isoelectric point (pI) of about 8 to about 8.5, and more preferably a pI value of about 8.3 as determined by isoelectric focussing

- (f) a connective tissue derived polypeptide having an isoelectric point (pI) of about 8.3 to about 8.8, and more preferably a pI value of about 8.6 as determined by isoelectric focussing
- 5 (g) a connective tissue derived polypeptide having an isoelectric point (pI) of about 8.8 to about 9.5, and more preferably a pI value of about 9.1 as determined by isoelectric focussing
- (h) a connective tissue derived polypeptide having an isoelectric point (pI) of about 6 to about 6.5, and more preferably a pI value of about 6.2 as determined by isoelectric focussing
- 10 (i) a connective tissue derived polypeptide having an isoelectric point (pI) of about 6.8 to about 7.5, and more preferably a pI value of about 7.2 as determined by isoelectric focussing

Individual polypeptides of the invention have been identified as fragments of known proteins. Peptides of up to about 30 amino acids were produced by subjecting a 15 polypeptide to trypsin digestion and then to Matrix Assisted Laser Desorption Ionisation (MALDI) mass spectrometry. The peptides have been compared to known proteins provided in reference databases.

Accordingly, in another embodiment, the present invention provides an isolated polypeptide obtainable by the method of the invention comprising the sequences and % 20 match with known proteins as disclosed in Figure 4, wherein the polypeptide or polypeptide fragment has anti-arthritis or anti-inflammatory.

Preferably, the connective tissue derived polypeptide in paragraph (a) *supra* comprises one or more of the following sequences following trypsin digestion:

- (K)LGNNV DFR(I)
- 25 (R)IESLP IKPR(G)
- (R)HLYPN GLPEE YSFLT TFR(M)
- (K)IMIGV ER(S)
- (R)SSATL FVDCN R(I)

Preferably, the connective tissue derived polypeptide in paragraph (b) *supra* 30 comprises one or more of the following sequences following trypsin digestion:

- (K)SVSFS YK(G)
- (K)IMIGV ER(S)
- (K)LGNNV DFR(I)
- (R)IESLP IKPR(G)
- 35 (K)HWSIW QIQDS SGK(E)
- (R)IGQDD LPGFD LISQF QIDK(A)

(R)HLYPN GLPEE YSFLT TFR(M)
(K)GLDGS LQTAQ FSNLP SLFDS QWHK(I)
(K)IMIGV ER(S)
(R)SSATL FVDCN R(I)

5 Preferably, the connective tissue derived polypeptide in paragraph (c) *supra* comprises one or more of the following sequences following trypsin digestion:

(K)SVSFS YK(G)
(K)IMIGV ER(S)
(K)LGNNV DFR(I)

10 (R)IESLP IKPR(G)
(K)HWSIW QIQDS SGK(E)
(R)IGQDD LPGFD LISQF QIDK(A)
(R)HLYPN GLPEE YSFLT TFR(M)
(K)GLDGS LQTAQ FSNLP SLFDS QWHK(I)

15 (K)IMIGV ER(S)
(R)SSATL FVDCN R(I)

Preferably, the connective tissue derived polypeptide in paragraph (d) *supra* comprises one or more of the following sequences following trypsin digestion:

(K)SVSFS YK(G)

20 (K)IMIGV ER(S)
(K)LGNNV DFR(I)
(R)IESLP IKPR(G)
(K)HWSIW QIQDS SGK(E)
(R)HLYPN GLPEE YSFLT TFR(M)

25 (K)GLDGS LQTAQ FSNLP SLFDS QWHK(I)
(R)SSATL FVDCN R(I)

Preferably, the connective tissue derived polypeptide in paragraph (e) *supra* comprises one or more of the following sequences following trypsin digestion:

(K)LGNNVDFR(I)

30 (R)IESLPPIKPR(G)
(R)IGQDD LPGFD LISQF QIDK(A)
(R)HLYPN GLPEE YSFLT TFR(M)
(R)SSATL FVDCN R(I)

35 Preferably, the connective tissue derived polypeptide in paragraph (f) *supra* comprises one or more of the following sequences following trypsin digestion:
(K)SVSFS YK(G)

- (K)IMIGV ER(S)
 - (K)LGNNV DFR(I)
 - (R)IESLP IKPR(G)
 - (K)HWSIW QIQDS SGK(E)
- 5 (R)IGQDD LPGFD LISQF QIDK(A)
(R)HLYPN GLPEE YSFLT TFR(M)
(K)IMIGV ER(S)
(R)SSATL FVDCN R(I)

Preferably, the connective tissue derived polypeptide in paragraph (g) *supra*
10 comprises one or more of the following sequences following trypsin digestion:
(K)LGNNV DFR(I)
(R)IESLP IKPR(G)
(R)IGQDD LPGFD LISQF QIDK(A)
(R)HLYPN GLPEE YSFLT TFR(M)

15 (R)SSATL FVDCN R(I)

- Preferably, the connective tissue derived polypeptide in paragraph (h) *supra*
comprises one or more of the following sequences following trypsin digestion:
(K)SVSFS YK(G)
(K)IMIGV ER(S)
- 20 (K)LGNNV DFR(I)
(R)IESLP IKPR(G)
(K)HWSIW QIQDS SGK(E)
(R)IGQDD LPGFD LISQF QIDK(A)
(R)HLYPN GLPEE YSFLT TFR(M)
- 25 (K)IMIGV ER(S)
(R)SSATL FVDCN R(I)
- Preferably, the connective tissue derived polypeptide in paragraph (i) *supra*
comprises one or more of the following sequences following trypsin digestion:
(K)SVSFS YK(G)
- 30 (K)IMIGV ER(S)
(K)LGNNV DFR(I)
(R)IESLP IKPR(G)
(K)HWSIW QIQDS SGK(E)
(R)IGQDD LPGFD LISQF QIDK(A)
- 35 (R)HLYPN GLPEE YSFLT TFR(M)
(K)IMIGV ER(S)

(R)SSATL FVDCN R(I).

Preferably, the connective tissue derived polypeptide in paragraphs (a)-(i) *supra* comprises an amino acid sequence having substantial identity to the sequence of Type IX collagen alpha 1 chain NC4 domain as depicted in Figure 6 or a homologue or 5 derivative thereof.

3. Polypeptides

The present inventors have substantially purified and established the identity of the type IX collagen alpha 1 chain polypeptide which is produced during the autolytic 10 processing of bovine cartilage matrix.

Also incorporated herein are amino sequences for collagen type IX alpha 1 NC4 domain derived from human, chick and rat connective tissue. Amino acid sequence comparisons of the bovine-chick NC4 domain polypeptides (see Figure 9), and bovine-human NC4 domain polypeptides (see Figure 10) show sequence overlap.

15 By "substantially purified polypeptide" we mean a polypeptide that has been at least partially separated from the lipids, nucleic acids, other polypeptides, and other contaminating molecules with which it is associated in its native state. Preferably, the substantially purified polypeptide is at least 60% free, preferably at least 75% free, and most preferably at least 90% free from other components with which they are naturally 20 associated. Furthermore, the term "polypeptide" is used interchangeably herein with the term "protein".

The % identity of a polypeptide is determined by GAP (Needleman and Wunsch, 1970) analysis (GCG program) with a gap creation penalty=5, and a gap 25 extension penalty=0.3. Unless stated otherwise, the query sequence is at least 15 amino acids in length, and the GAP analysis aligns the two sequences over a region of at least 15 amino acids. More preferably, the query sequence is at least 50 amino acids in length, and the GAP analysis aligns the two sequences over a region of at least 50 amino acids. Even more preferably, the query sequence is at least 100 amino acids in 30 length and the GAP analysis aligns the two sequences over a region of at least 100 amino acids.

With regard to the defined polypeptides/enzymes, it will be appreciated that % identity figures higher than those provided above will encompass preferred embodiments. Thus, where applicable, in light of the minimum % identity figures, it is 35 preferred that the polypeptide comprises an amino acid sequence which is at least 60%, more preferably at least 65%, more preferably at least 70%, more preferably at least 75%, more preferably at least 76%, more preferably at least 80%, more preferably at

least 85%, more preferably at least 90%, more preferably at least 91%, more preferably at least 92%, more preferably at least 93%, more preferably at least 94%, more preferably at least 95%, more preferably at least 96%, more preferably at least 97%, more preferably at least 98%, more preferably at least 99%, more preferably at least 99.1%, more preferably at least 99.2%, more preferably at least 99.3%, more preferably at least 99.4%, more preferably at least 99.5%, more preferably at least 99.6%, more preferably at least 99.7%, more preferably at least 99.8%, and even more preferably at least 99.9% identical to the relevant nominated SEQ ID NO.

As used herein, the term "biologically active fragment" refers to a portion of the defined polypeptide which still maintains anti-arthritis or anti-inflammatory activity (whichever is relevant). Such biologically active fragments can readily be determined by serial deletions of the full length protein, and testing the activity of the resulting fragment.

Amino acid sequence mutants/variants of the polypeptides/enzymes defined herein can be prepared by introducing appropriate nucleotide changes into a nucleic acid encoding the polypeptide, or by *in vitro* synthesis of the desired polypeptide. Such mutants include, for example, deletions, insertions or substitutions of residues within the amino acid sequence. A combination of deletion, insertion and substitution can be made to arrive at the final construct, provided that the final protein product possesses the desired characteristics.

In designing amino acid sequence mutants, the location of the mutation site and the nature of the mutation will depend on characteristic(s) to be modified. The sites for mutation can be modified individually or in series, e.g., by (1) substituting first with conservative amino acid choices and then with more radical selections depending upon the results achieved, (2) deleting the target residue, or (3) inserting other residues adjacent to the located site.

Amino acid sequence deletions generally range from about 1 to 30 residues, more preferably about 1 to 10 residues and typically about 1 to 5 contiguous residues.

Substitution mutants have at least one amino acid residue in the polypeptide molecule removed and a different residue inserted in its place. The sites of greatest interest for substitutional mutagenesis include sites identified as the active or binding site(s). Other sites of interest are those in which particular residues obtained from various strains or species are identical. These positions may be important for biological activity. These sites, especially those falling within a sequence of at least three other identically conserved sites, are preferably substituted in a relatively conservative manner. Such conservative substitutions are shown in Table 1.

Furthermore, if desired, unnatural amino acids or chemical amino acid analogues can be introduced as a substitution or addition into the polypeptides of the present invention. Such amino acids include, but are not limited to, the D-isomers of the common amino acids, 2,4-diaminobutyric acid, α -amino isobutyric acid, 4-aminobutyric acid, 2-aminobutyric acid, 6-amino hexanoic acid, 2-amino isobutyric acid, 3-amino propionic acid, ornithine, norleucine, norvaline, hydroxyproline, sarcosine, citrulline, homocitrulline, cysteic acid, t-butylglycine, t-butylalanine, phenylglycine, cyclohexylalanine, β -alanine, fluoro-amino acids, designer amino acids such as β -methyl amino acids, Ca -methyl amino acids, Na -methyl amino acids, and 10 amino acid analogues in general.

TABLE 1. Exemplary substitutions.

Original Residue	Exemplary Substitutions
Ala (A)	val; leu; ile; gly
Arg (R)	lys
Asn (N)	gln; his
Asp (D)	glu
Cys (C)	ser
Gln (Q)	asn; his
Glu (E)	asp
Gly (G)	pro, ala
His (H)	asn; gln
Ile (I)	leu; val; ala
Leu (L)	ile; val; met; ala; phe
Lys (K)	arg
Met (M)	leu; phe
Phe (F)	leu; val; ala
Pro (P)	gly
Ser (S)	thr
Thr (T)	ser
Trp (W)	tyr
Tyr (Y)	trp; phe

Val (V)	ile; leu; met; phe, ala
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Also included within the scope of the invention are polypeptides of the present invention which are differentially modified during or after synthesis, e.g., by biotinylation, benzylation, glycosylation, acetylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to an antibody molecule or other cellular ligand, etc. These modifications may serve to increase the stability and/or bioactivity of the polypeptide of the invention.

Polypeptides of the present invention can be produced in a variety of ways, including production and recovery of natural proteins, production and recovery of recombinant proteins, and chemical synthesis of the proteins. In one embodiment, an isolated polypeptide of the present invention is produced by culturing a cell capable of expressing the polypeptide under conditions effective to produce the polypeptide, and recovering the polypeptide. A preferred cell to culture is a recombinant cell of the present invention. Effective culture conditions include, but are not limited to, effective media, bioreactor, temperature, pH and oxygen conditions that permit protein production. An effective medium refers to any medium in which a cell is cultured to produce a polypeptide of the present invention. Such medium typically comprises an aqueous medium having assimilable carbon, nitrogen and phosphate sources, and appropriate salts, minerals, metals and other nutrients, such as vitamins. Cells of the present invention can be cultured in conventional fermentation bioreactors, shake flasks, test tubes, microtiter dishes, and petri plates. Culturing can be carried out at a temperature, pH and oxygen content appropriate for a recombinant cell. Such culturing conditions are within the expertise of one of ordinary skill in the art.

25 ***4. Preparation and administration of pharmaceutical compositions***

Compositions of the invention may be prepared from one or more polypeptide. Additional polypeptide fragments or peptides can be identified by routine experimentation in light of the present specification, claims and figures. A method for identifying peptide fragments having stimulatory activity is described, for example, in US5,399342.

The pharmaceutical compositions may be for human or animal usage in human and veterinary medicine and will typically comprise any one or more of a pharmaceutically acceptable diluent, carrier or excipient. Acceptable carriers or diluents for therapeutic use are well known in the pharmaceutical art, and are described for example in *Remington's Pharmaceutical Sciences* Mack Publishing Co. (A.R.

Gennaro edit. 1985). The choice of pharmaceutical carrier excipient or diluent can be selected with regard to the intended route of administration and standard pharmaceutical practice. The pharmaceutical compositions may comprise as, or in addition to, the carrier, excipient or diluent, any suitable binder, lubricant, suspending agent, coating agent, or solubilizing agent.

5 It is well known in the art that there may be different composition/ formulation requirements dependant on the different delivery systems.

According to the present invention non-invasive formulations are particularly preferred. Where appropriate, the pharmaceutical compositions can be administered by 10 inhalation, orally or intranasally, in the form of suppository or pessary, topically in the form of a lotion, solution, cream, ointment, or dusting powder, by use of a skin patch, orally in the form of tablets containing excipients such as starch or lactose, or in capsules, chewables or ovules either alone or in admixture with excipients, or in the 15 form of elixirs, solutions, syrups or suspensions containing flavouring or colouring agents.

For buccal or sublingual administrations, the compositions may be administered for example in the form of tablets or lozenges which can be formulated in a conventional manner.

Oral formulations include such normally employed excipients as, for example, 20 pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, and the like. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and contain 10% to 95% of active ingredient, preferably 25% to 70%.

Capsules, tablets and pills for oral administration to a patient may be provided 25 with an enteric coating comprising, for example, Eudragit "S", Eudragit "L", cellulose acetate, cellulose acetate phthalate or hydroxypropylmethyl cellulose.

Intranasal formulations are described and administration of larthritic collagen type II and larthritic collagen type IX are described for example in Lu *et al* (1999) 30 Different therapeutic and bystander effects by intranasal administration of homologous type II and type IX collagens on the collagen-induced arthritis and pristane-induced arthritis in rats, *Clinical Immunology* Vol 90 pp 119-127 (1999).

In another example, the pharmaceutical composition of the present invention may be formulated to be delivered using a mini-pump or by a mucosal route, for example, as a nasal spray or aerosol for inhalation or ingestible solution.

35 Where the agent is to be delivered mucosally through the gastro-intestinal mucosa, it should be able to remain stable during transit through the gastro-intestinal

tract; for example, it should be resistant to proteolytic degradation, stable antacid, pH and resistant to the detergent effects of bile.

Preferably, the compositions of the invention are administered by a non-invasive route. Preferably, the non-invasive route comprises oral administration, or enteral 5 administration, nasal administration or by inhalation.

In an alternate embodiment, compositions of the invention can be injected parenterally for example, intravenously, intramuscularly or subcutaneously.

For parenteral administration, the compositions may be best used in the form of a sterile aqueous solution which may contain other substances, for example enough 10 salts or monosaccharides to make the solution isotonic with blood. The preparation may also be emulsified, or encapsulated in liposomes.

After formulation, the immuno-protective composition may be incorporated into a sterile container which is then sealed and stored at a low temperature, for example 4°C, or it may be freeze-dried. Lyophilisation permits long-term storage in a stabilised 15 form.

5. Treatment and protection of an individual

The effects observed for the polypeptides on inflammation and collagen induced arthritis in rats also provide application for the polypeptides, and mixtures thereof, in 20 the treatment, and protection of an individual to arthritis and other degenerative diseases. Further the effects observed provide application of the polypeptides in the tolerisation of an individual to the antigenic effects of cartilage components. Further, the finding provide application to methods of restoration of connective tissues, particularly in inflammatory and degenerative tissue diseases such as rheumatoid 25 arthritis and osteoarthritis.

Polypeptides according to the invention that have been shown to have anti-inflammatory and/or anti-arthritis activity can be further tested for safety and efficacy in other animal models, and then proceed to clinical trials in humans, if desired. Naturally, for veterinary applications, no clinical trial in humans is required. Those 30 polypeptides that are safe and efficacious in animals or humans can be administered to an appropriate subject to treat a connective tissue disease, or alternatively to protect against connective tissue disease by the process of tolerisation.

Rodent models of connective tissue disease are well known. For example, rat models for collagen induced arthritis and pristane induced arthritis rats are described in 35 Lu *et al* (1999) (*supra*). Murine collagen induced models of arthritis are also described in Myers *et al* (2002) (*supra*).

- Methods and pharmaceutical formulations for the treatment of autoimmune arthritis and animal models in mammals, including humans, by the oral, enteral or by-inhalation administration of whole collagen type II protein or biologically active peptide fragments of collagen type II are described in US 5,399347 (Trentham *et al*).
5 Further, methods and formulations for evaluating the efficacy of oral type II collagen in the treatment of juvenile rheumatoid arthritis (JRA) are described in Barnett *et al* (1996) (*supra*).

Intranasal formulations are described and administration of larthritic collagen type II and larthritic collagen type IX are described in Lu *et al* (1999) (*supra*).

10 The present invention provides methods of treatment of arthritis or other degenerative disease in animals, preferably mammals and more preferably humans.

"Treatment and protection" includes both prophylactic and therapeutic measures to prevent the onset and appearance of a connective tissue disease as well as to prevent the onset and appearance of an abnormal immune response against the body's own
15 tissues involved in autoimmune disease. The term also encompasses the suppression or mitigation of the abnormal (cell and/or humoral) immune response to the body's own collagen or more generally cartilage as well as the alleviation or elimination of clinical symptoms after the onset (ie. clinical manifestation) of autoimmune disease.

"Autoimmune disease" is defined as a malfunction of the immune system of
20 mammals, in which the immune system fails to distinguish between foreign substances within the mammal and/or autologous tissues or substances and, as a result, treats autologous tissues and substances as if they were foreign and mounts an immune response against them.

25 Tolerance

The present invention provides methods for inducing tolerance in an individual to at least one antigenic component of cartilage.

As used herein "tolerance" refers to the active state of specific immunologic nonresponsiveness induced by prior exposure to an antigen. Experimentally induced
30 tolerance may be defined as a state in which an animal will fail to respond to an antigen that will normally be immunogenic. Immunologic tolerance does not simply reflect the absence of an immune response, but rather an active response of the immune system that exhibits antigenic specificity and memory - the hallmarks of any immune response. In experimentally induced tolerance a foreign antigen is administered under certain
35 conditions that promotes a state of tolerance rather than immune activation. Antigen structure, dosage and route of administration each partly determine whether the

response of the immune system will lead to immunity or tolerance. Experimental evidence demonstrating the role of these factors is provided in J. Kuby in *Immunology*, 2nd ed, WH Freeman and Company, 1994, Chapter 16.

- As used herein the terms "immunotherapy" and "tolerance therapy" refer to any general method resulting in tolerance or immunological prophylaxis. In vivo, these therapies typically entail a series of parenteral or oral administrations of the immunogenic material over an extended period of time. In one embodiment, "tolerance therapy" refers to a method for the down-regulation of an immune response, e.g., to suppress an inflammatory response to an auto-antigen.
- Oral administration of antigens is an effective method of inducing peripheral T-cell tolerance. This phenomenon, often referred to as oral tolerance, has been well studied in various models of autoimmune diseases in animals including encephalomyelitis, uveitis, diabetes, myasthenia gravis, and arthritis. The mechanisms for inducing tolerance, however, are not completely understood. All of the known mechanisms for tolerance induction, including clonal anergy, clonal deletion, and regulation by IL-4, IL-10, or TGF-beta-mediated active suppression may have a role in oral tolerance. Generally, higher doses of antigen are reported to induce anergy or clonal deletion whereas low doses induce cytokine regulation and active suppression.
- Active suppression describes the regulation of one lymphocyte subset by another in an antigen-specific manner. Depending on the antigen and disease state, the suppressor cells may be CD4+ and/or CD8+ T-lymphocytes which migrate from peripheral lymphoid tissues, such as spleen and peripheral lymph nodes, to sites of disease activity. Adoptive transfer of these cells to naive recipients has confirmed the role of these cells in active suppression in rodent models of ovalbumin-induced hypersensitivity, and multiple sclerosis. *In vitro* evidence of active suppression is demonstrated by data showing that tolerized lymphocytes from animals can suppress proliferation of other antigen-specific T-lymphocytes across a transwell cell culture system (Faria and Weiner, "Oral tolerance: mechanisms and therapeutic applications," *Adv. Immunol.*, 73:153-264, 1999).
- Clonal anergy refers to unresponsiveness of antigen-specific T-lymphocytes, which is characterized by diminished proliferation after exposure to an antigen, and is involved in oral tolerance in several animal models. Anergy could be the result of production of soluble suppressive factors by CD4+ or CD8+ T-lymphocytes themselves, other T-lymphocytes or cells in the local environment, or as result of decreased expression of appropriate costimulatory molecules. Clonal deletion refers to the elimination of antigen-specific T-lymphocytes, but has been reported rarely as a

mechanism of oral tolerance to an antigen (Chen, Inobe, Marks, Gonnella, Kuchroo, Weiner, "Peripheral deletion of antigen-reactive T cells in oral tolerance," Nature, 376:177-180, 1995).

- The soluble mediators that suppress the immune response during oral tolerance
- 5 are derived mainly from regulatory or suppressor T-lymphocytes (Faria and Weiner 1999, *supra*). There are four types of T-lymphocytes described by the cytokines they produce: Th1-type that produce interleukin-2 (IL-2) and gamma interferon (γ FN); Th2-type that produce IL-4 and IL-10; Th3-type that produce high levels of transforming growth factor beta (TGF- β), alone, or in conjunction with very low levels
- 10 of IL-4, IL-10, or γ .IFN; and Tr1 cells that produce high levels of IL-10 in conjunction with low levels of TGF- β . Since Th3, Th2, and Tr1-T-lymphocytes have been shown to be the major mediators of active suppression induced by oral tolerance, then TGF- β , IL-4 and IL-10 are believed to be key cytokines in this process. Further reports showing that oral tolerance induction occurred in the absence of these cytokines suggests that
- 15 other mediators or cells could suppress the immune response.

- Studies of tolerance have focused primarily on the effect of the tolerizing antigen on T-lymphocyte function, and the role of T-lymphocytes in suppressing immune activation. However, immune responses to any antigen require interactions between APC's and T-lymphocytes, and the T-lymphocyte may affect APC function.
- 20 Therefore, down-regulated antigen presentation by APC's from tolerized hosts could also contribute to tolerance induction either indirectly as a result of interactions with suppressor T-lymphocytes, or possibly as a result of direct effects of the tolerizing antigen on the APC.

- As used herein "degenerative disease", "degenerative condition" or
- 25 "degenerative disorder" are used interchangeably to refer to conditions that are characterised by a breakdown of a biological tissue, more particularly a connective tissue. Connective tissue refers to those animal tissue that supports organs, fills spaces between them, or performs mechanical functions such as connecting muscles to bone (tendons and ligaments) or providing low friction weighing surface as in articular
- 30 cartilage. Connective tissues are characterized by their relatively avascular matrices and low cell densities. The most abundant connective tissues are the reticular stroma, muscle, adipose tissue, cartilage and bone.

- The term "tissue" as used herein refers to matrices which contain similarly specialised cells that perform a common function. As used herein, tissue is intended to
- 35 include an organ composed of a given tissue, and to the cells individually or collectively that compose the tissue.

As used herein "autoimmune disease" refers to a disease characterised by a humoral (eg., antibody-mediated), cellular (eg., cytotoxic T-lymphocyte-mediated), or a combination of both types of immune responses to epitopes on self-antigens. The immune system of the affected individual activates inflammatory cascades aimed at 5 cells and tissues presenting those specific-self antigens. The destruction of the antigen, tissue, cell type or organ attacked gives rise to further symptoms of the disease. In a preferred embodiment of the invention the disease is selected from the group consisting of rheumatoid arthritis, osteoarthritis, disc degeneration and osteoporosis.

The terms self-antigens or auto-antigens are used interchangeably to refer to an 10 antigen that is endogenous to an individual's physiology, that is recognised by either the cellular component (eg T-cell or B-cell receptors) or humeral component (antibodies) of that individual's system.

MODES FOR CARRYING OUT THE INVENTION

1. Experimental Protocols

Bovine, ovine, cervine or porcine tracheal cartilage or nasal cartilage, chicken sternal cartilage, or skeletal shark cartilage or deer antler cartilage were freed of adhering soft tissues mechanically or as described previously US Patent 5,399,347 Mar 1995, US Patent 5,364,845 Dec 1996, US Patent 6,025,327 Feb 2000). These cleaned 20 hyaline cartilages were rinsed with water, minced into 1 mm or 3 mm sizes, freeze dried and stored at -20 °C. Bovine tracheal chondroitin sulfate A (ChSA) was purchased from Sigma Chemical Co, USA or was obtained as a gift from Bioiberica, Barcelona, Spain (batch 1/0015, batch 05/2001, batch 18/11/99). All other chemicals were of analytical grade and were purchased from local suppliers.

25

Release of Glycosaminoglycan Peptide (GAG-peptide) Complexes and polypeptides from the Cartilage Powders

Studies on the kinetics of release of the GAG-peptides and polypeptides from the cartilage powders were performed using different buffers (eg sodium or calcium acetate or dilute acetic acid) to give various products referred to herein as "Peptacan(s)" 30 and was undertaken under a variety of conditions. The objective of these experiments was to determine the effects of (i) particle size - 3mm,5mm, (ii) different pHs eg. pH range 3.5-7.0, (iii) different temperatures, 4°C, 25°C and 37°C, and (iv) animal species and tissue locations on the rate of autolysis and product release into the aqueous phase. 35 All the experiments were performed, with stirring and release of sulphated GAGs and polypeptides monitored over 24 hours. In the initial studies undertaken, the primary

observation was that subjecting particles of cartilages to autolysis in aqueous buffers maintained within the pH range of 4.0-7.0, particularly 4.5, preferably at 37°C for periods up to 24 hours specifically released more than 80% of the total sulfated glycosaminoglycans (S-GAG) into solution. Studies also showed that the rate of release was dependent on the cartilage particle size, the smaller preparations undergoing more rapid release. However, by 24 hours the yields obtained were the same. The pH and temperature were found to be important determinants of the rate of release which indicated that the release process was mediated by endogenous enzymes present within the solid tissues. This proposed mechanism was confirmed by 5 undertaking autolysis experiments in the absence and presence of specific enzyme inhibitors. Since it was found that the addition of N-ethylmaleimide produced the most significant inhibition of GAG-peptide and polypeptides release into the aqueous medium we consider that the cysteine class of proteinases, such as the Cathepsins, were 10 the major, but not exclusive, contributors to the autolytic process.

15 The aqueous phase was separated from the cartilage powders by filtration and the filtrate centrifuged to remove fine particles and then neutralised to pH 7.0 by addition of an alkaline solution containing the desired cation. These Peptacan solutions after chemical analysis were either freeze dried and used directly for pharmacological studies. The freeze dried Peptacans were used as stock material for the preparation of 20 dialysed and fractionated preparations as described below.

Alternatively the Peptacans could be isolated from the aqueous solutions obtained from the cartilage digests by precipitation with excess quantities of acetone, ethanol or methanol, usually by adding 3-5X the volume of the aqueous extracts. The precipitates so obtained would be washed with absolute ethanol and dried under 25 vacuum then stored in a vacuum desiccator.

The process of the present invention is essentially non-disruptive leaving the type II collagen matrix and cells of the tissue intact, and the absence of DNA in the autolysis media. The efficiency of the autolytic process was also influenced by the animal species and anatomical location from where the cartilage was derived as well as 30 the nature of the buffers used.

For the further experiments described herein, the results were obtained following subjecting bovine tracheal cartilage to autolysis with calcium acetate buffer. For the purpose of convenience, the product obtained by this process is referred to herein as Calcium Peptacan (CaP).

Separation of Glycosaminoglycan Peptides (GAG-peptides) from polypeptides in Peptacan preparations by Ion-exchange solid phase media (see schema shown in Figure 2)

- Freeze-dried Peptacans was dissolved in 0.1M calcium chloride buffered with
- 5 Tris-HCl to a pH of 7.2 (application buffer) to afford sample concentrations of 4.0 mg/ml. To these solutions was added pre-swollen DEAE-Sepharose-6B to achieve a final concentration of the ion exchanger of 100mg/mL. This mixture was maintained at room temperature with gentle agitation for 16 hours in 5mL stoppered centrifuge tubes. The tubes were then centrifuged at 1000rpm for 5 mins and the supernatant decanted
- 10 off. To the remaining pellet was added 1mL of the application buffer and the tubes gently shaken, centrifuged again and the application buffer washings added to the original supernatant. The supernatant and washings contains the proteins and polypeptides in the Peptacan preparations.
- 15 Fractionation of the Peptacan proteins and polypeptides
- The supernatant and washings from the ion exchange process were subjected to diafiltration using a 1000Da cut-off ultrafiltration membrane (eg, YC10) or a tangential flow ultrafiltration (TFF) cartridge of similar cut-off (Millipore Australia Pty Ltd, Sydney, Australia), to remove the inorganic ions. The diafiltrated de-salting
- 20 polypeptide solution was then freeze-dried and stored at -20°C. Subjecting aqueous solutions of these polypeptides to further fractionation using TFF membranes of different molecular weight cut-offs afforded polypeptides of predetermined molecular size. For example using a PLTC regenerated cellulose membrane with an exclusion size of 30,000 (Millipore Australia Pty Ltd, Sydney, Australia) afforded a mixture of
- 25 polypeptides in the retentate with molecular weights greater than 30,000Da. These proteins and polypeptides were freeze dried and assigned the code of INR-307 for subsequent experiments. The dialysate from the first TFF contained polypeptides with molecular weights less than 30,000Da but greater than 1,000Da. This fraction was designated the code INR-126 for subsequent experiments. In addition the dialysate
- 30 from the 30,000Da TFF step was also subject to TFF using a polyethersulfone spiral cartridge (Millipore Australia Pty Ltd, Sydney, Australia) with an exclusion size of 10,000 Da which provided a retentate containing polypeptides with molecular weights > 10,000 Da. These polypeptides were assigned the code INR-195 for subsequent experiments. The efficiency of the separations of these polypeptides into the molecular
- 35 ranges cited was confirmed by SDS-PAGE using proteins of known molecular weight as standards such as those shown in Figures 3 and 4.

Further fractionation of the polypeptide solutions can be achieved using any one or combination of techniques such as, for example, gel filtration, ultrafiltration, SDS PAGE electrophoresis, 2D gel electrophoresis, and reverse phase HPLC using established methods (see for example,Eyre D, et al. Collagen type IX: evidence for covalent linkages to type II collagen in cartilage. FEB 220:337-341,1987).

Detailed preparation of INR-195

In this procedure the supernatant and washings containing the polypeptide components obtained from ion exchange separation of calcium peptacan using DEAE-Sepharose were transferred to a reservoir connected via a peristaltic pump to a 10kD PLAC (PL series Cellulose or polysulfone 0.93 square metre spiral cartridge (Millipore Australia Pty Ltd). The peptide containing solution is then subjected to tangential flow filtration for 6 hours by addition of purified water to the reservoir to dialysis off the small inorganic ions used for ion exchange procedure as well as peptides with molecular weights below the cut-off of the membrane. The retentate was then concentrated by diafiltration in the same apparatus, collected and water removed by freeze drying. In such a procedure the product obtained by this method was designated as INR-195 and was used for the rat CIA experiments described herein.

20 **2. BIOLOGICAL ACTIVITY**

Determination of collagen or collagen peptide content in preparations by assay for hydroxyproline

The collagen content of polypeptides separated by ion exchange was estimated by measuring the concentration of the amino acid hydroxyproline which is unique to this protein. Each freeze dried sample was directly dissolved in H₂O (10 mg/ml) and then hydrolysed in 5 N HCl at 110 °C for 24 h. The hydrolysed sample solution was neutralised to pH 7 before dilution and analysis. The hydroxyproline concentration in these solutions was determined using the method of Stegman and Stalder (Stegman H and Stalder K. Determination of Hydroxyproline. Clin. Chim. Acta 18:267-273, 1967) by using a L-hydroxyproline standard and measuring the absorbance at 562 nm after the addition of chloramine T and p-dimethylaminobenzaldehyde to develop the chromophore. The hydroxyproline concentration was multiplied by 7.4 to give an estimate of the collagen content.

Determination of Protein content of preparations content by the Bicinchoninic Acid (BCA) assay

The total protein content of polypeptide samples was determined using BCA assay (Smith PK, Krohn RI, Hermanson GT, Mallia AK, Gartner FH, Provenzano MD, Fujimoto EK, Goeke NM, Olson BJ and Klenk DC. Anal. Biochem. 150, 76–85, 1985). Freeze dried polypeptide samples were directly dissolved in H₂O to provide a 2.0 mg/ml solution and 20 µl of each sample solution was added to a well of 96-well plates. Just prior to assay, 50 parts of reagent 1 (0.4% NaOH; 1.7% Na₂CO₃; 0.95% NaHCO₃; 1.0% bicinchoninic acid; 0.16% Na₂-tartrate) was mixed with reagent 2 (4% CuSO₄.5H₂O). Two hundred micro litres of this working reagent was added to the sample solution. After incubation at 37°C for 60 min the absorbance A₅₆₂ was read using a Thermomax microplate reader. Bovine serum albumin (BSA) or highly purified gelatine (Gibco) at 0–10 µg/well were used to construct a standard curve.

15 Analysis of polypeptides separated by ion exchange using SDS-Polyacrylamide Gel Electrophoresis (SDS-PAGE)

Freeze dried polypeptide samples were dissolved in H₂O and then mixed 1:1 with 2x sample loading buffer (0.07 M TrisHCl, 1.5% SDS, 20% glycerol, 0.2M DTT and 0.1% BPB) to achieve the final concentrations of 4.0 – 20 mg/ml. The samples 20 were boiled in a water bath for 5 min. 20 µl of above samples were loaded into the wells of 8 – 16 % pre-cast Tris-glycine gel (Norvex). SeeBlue pre-stained low molecular weight range protein markers (Norvex) were loaded into wells on the left-hand side of the gel and electrophoresis was performed at 125 V for 2 h. The gel was stained in Coomassie blue R250 solution (40% ethanol, 10% acetic acid and 0.2% 25 Coomassie R250) for 30 min and destained in a solution containing 10% ethanol and 7.5% acetic acid for 16 h. The gel was dried in a Bio-Rad Gelair drier.

SDS-PAGE of the polypeptides separated from the GAG-peptides by the ion exchange procedure showed the presence of a number of bands the most abundant of which had molecular weights of 36kDaltons or less (Figure 2).

30

Analysis of polypeptides separated by ion exchange using two-Dimensional gradient SDS-PAGE

Freeze dried polypeptide samples (6.5mg) were dissolved in H₂O and sonicated. Samples were then centrifuged at 20,000g for 10 minutes then were loaded via in-gel 35 rehydration methods for Isoelectric Focusing (IEF) using 11 cm gradient strips over a pH of 3-10. First Dimension focusing was at 35,000Vh. The second dimension used

separating gradient 8-18%T criterion format polyacrylamide slab gels. This second dimension electrophoresis was run at 1 hour @ 5mA/gel and 4 hours @ 15mA/gel. Gels were stained using SYPRO Ruby fluorescent stain then scanned to produce a digital image.

- 5 Two dimensional electrophoresis of the polypeptides separated from the GAG-peptides by the ion exchange procedure revealed the presence of at least 21 polypeptides (Figure 4).

10 Tryptic digestion and Matrix assisted laser desorption ionisation (MALDI) mass spectrometry

Following two-dimensional gradient SDS-PAGE of samples they were subjected to an in gel 16 hour tryptic digest at 37°C. The resulting peptides were extracted from the gel with a 10% (v/v) acetonitrile, 1% (v/v) TFA solution. The samples were then cleaned up and concentrated using ZipTip. A 1µL aliquot of each 15 was spotted onto a sample plate with 1µL of matrix (a-cyano-4-hydroxycinnamic acid, 8mg/mL in 70% v/v AcN, 1% v/v TFA) and allowed to air dry. Matrix assisted laser desorption ionisation (MALDI) mass spectrometry was then performed with a Micromass Maldi Time of Flight Mass Spectrometer. A nitrogen laser (337 nm) was used to irradiate the sample. The spectra were acquired in reflectron mode in the mass 20 range 750 to 3500 Da. A near point calibration was applied.

The peptide masses of the monoisotopic peak of the peptides from this analysis were searched against Bovine using ProteinLynx on MassLynx and Mammalia data bases using PeptIdent on Expasy.

25 Rat collagen induced arthritis (CIA)

Two protocols, which are summarized in Figure 11, were used to evaluate the anti-arthritis activities of the polypeptides isolated in this invention. The toleragenic protocol required that the polypeptides dissolved in water were given orally each day to Female Wistar rats (160-180 gm) 7 days before inducing the arthritis by the inoculation 30 with 250 µg bovine tracheal type II collagen, given as 6 divided injections into their tailbase. In the therapeutic/prophylactic protocol the polypeptides were administered orally on the same day as the arthritis was induced in the animals and everyday thereafter.

The following signs of arthritis were assessed from Day 11 onwards but 35 recorded for each experimental group on days 15 and 18 (see Figures 12 and 13).

- Rear paw swelling, fore paw swelling (measured as the change in mm relative to non-arthritis controls) and an overall arthritis score (scored 0-4+) determined on the basis of overall inflammation and other signs of disease e.g. piloerection, diminished mobility, poor grooming etc were determined as described previously (Lu S *et al*, Different 5 therapeutic and bystander effects by intranasal administration of homologous type II and type IX collagens on the collagen- induced arthritis and Pristane-induced arthritis in rats. Clin Immunol. 90:119-127, 1999).

Preparations of stained histological sections of rat joints.

- 10 Following sacrifice of the experimental animals rear and front paw joints were removed surgically and immediately placed in neutral buffered formaldehyde and processed for preparation of H and E and toluidine blue stained histological sections as described previously (Smith MM, Numata Y and Ghosh P, Effects of calcium pentosan polysulfate on joint inflammation and pouch fluid levels of leukocytes, 15 nitric oxide and interleukin-6 in a rat model of arthritis. Current Therapeutic Research, 60: 561-576, 1999).

3. DISCUSSION

- Positive identification of 17 of the polypeptides took account of the percentage 20 of sequence coverage, how well the masses matched the significant peaks in the MS spectra, the number of missed cleavages (if missed cleavages were present their location in the sequence was critical) and how well the MW and pI of the identified protein match. These sequences and their % match with known proteins are shown in Figure 5.

- 25 The most abundant polypeptide fragments present in those isolated from CaP by the ion exchange method were derived from the NC4 domain of the type IX collagen α 1 chain [Molecular weight: 27,139Da, (Vasios G, Nishimura I, Konomi H, van der Rest M, Cartilage Type IX collagen-proteoglycan contains a large amino-terminal globular domain encoded by multiple exons. J Biol Chem 263: 2324-2329, 1988)]. This is evident by combining the sequences obtained from the trypsin generated products 30 shown in Figure 5 for: Polypeptide 10, Polypeptide 13, Polypeptide 14, Polypeptide 15, Polypeptide 16, Polypeptide 17, Polypeptide 18, Polypeptide 20 and Polypeptide 21 and super-imposing them on part of the bovine NC4 domain of the α 1(IX) chain as shown in Figure 8. This conclusion is also supported by comparison of the observed 35 peptide sequences with the published NC4 domain of the α 1(IX) chain from chick sterna (Vasios G, Nishimura I, Konomi H, van der Rest M, Cartilage Type IX collagen-

proteoglycan contains a large amino-terminal globular domain encoded by multiple exons. J Biol Chem 263: 2324-2329, 1988) and shown in Figure 9. Furthermore the estimated molecular weights and isoelectric points of Polypeptide 13, Polypeptide 14, Polypeptide 15, Polypeptide 16, Polypeptide 17, and Polypeptide 18 shown in figure 6
5 are consistent with their origin as the NC4 domain of the α 1(IX) chain which has a molecular weight of about 27,00Da and isoelectric point of 9.7.

While the 4 non-collagenous domains (NC1, 2, 3 and 4, Figure 1) along the type IX collagen α 1 chain are known to be the most susceptible regions to proteolytic cleavage by a wide range of proteinases, the NC4 domain is the most venerable of these
10 regions because of its physical extension beyond the COL3 domain and the rest of the alpha chain which together with the other 2 alpha chains lies on the surface of the type II collagen fibril. The results obtained previously also indicate that the endogenous cathepsin family of proteinases were largely responsible for the release of matrix peptides fragments from cartilage under the conditions described herein. Significantly,
15 that the NC4 domain of type IX collagen alpha 1 chain is rich in Arginine residues which constitutes part of the preferred cleavage sites for the cathepsins (Maciewicz RA, Etherington DJ. A comparison of four cathepsins (B,L,N and S) with collagenolytic activity from rabbit spleen, Biochem. J, 256: 433-4440, 1988).

The finding of a fragment (Polypeptide 2) of bovine cartilage oligomeric matrix
20 protein (COMP) (peptides 2 and 3) in the polypeptides from the ion-exchange supernatants is also supportive of the proteolytic cleavage of the NC4 domain of type IX collagen alpha 1 chain. COMP through its C-terminal domain is known to interact with the non-collagenous domains (NC1-4) of the type IX collagen alpha 1 chain and could be enzymatically processed when the NC4 domain is cleaved from the rest of the
25 type IX collagen alpha-1 chain since these two proteins are strongly associated and play key structural roles in the assembly of the extracellular matrix of cartilage. As already mentioned, the type IX collagen is located on the surface of the type II collagen fibrils where it serves as cross linking units between fibrils and itself. It was therefore surprising to find that none of the polypeptides isolated contain any peptides
30 originating from the type II collagen molecule suggesting that the autolytic process is selective for the NC4 domain of the type IX collagen molecule.

Fragments of Bovine Serum Albumin (Molecular weight: 69294) (Polypeptide 7, Polypeptide 8, Polypeptide 9, Polypeptide 11, Polypeptide 12) were also found in the polypeptide fraction of CaP (Figure 5). The presence of fragments of this protein was not unexpected in view of the large reservoir available in the blood of tissues adjacent to the tracheal cartilage.
35

- Neutrophil cytosol factor 1 (Molecular weight: 45346) (Polypeptide 1 and Polypeptide 9), Odorant-binding protein (Molecular weight: 18503) (Polypeptide 19) have not previously been reported to be present in cartilage and their functions, if any, are therefore unknown. Odorant-binding protein has however, been identified in bovine nasal mucosa endothelium which is physically close to the trachea. It is possible that this protein is sequestered to the tracheal cartilage and is not in fact a chondrocyte biosynthetic product. Since bovine odorant protein is not a cartilage derived antigen it would not be expected to be effective in the collagen induced arthritis model used to identify anti-arthritis activity in the present application.
- 5 In this respect it was significant that the polypeptides retained by using a TFF membrane with a protein cut-off of >30,000Da were in-active in the rat CIA model (data not shown). On the other hand those polypeptides obtained in the dialysate with molecular weights <30,000Da (INR-126 and INR-195) were active both active as tolerants and prophylactic anti-arthritis agents (Figures 12-15). Furthermore, since the
- 10 anti-arthritis activity of INR-126 (MW range 1000Da-30,000Da) appeared to be only slightly more active as a toleragen in the CIA model than INR-195 (MW range 10,000Da- 30,000Da) it may be deduced that the majority of the anti-arthritis activity resides in polypeptides within the MW range of 10,000-30,000Da which corresponds to peptides 11, 12, 13, 14, 15, 16, 17, 18, 20, 21 (Figure 6).
- 15 20 The NC4 domain of the α 1(IX) chain or fragments derived from it have not previously been reported to exhibit anti-arthritis activity.